Fisheries and Oceans Canada | Pêches et Océans Canada
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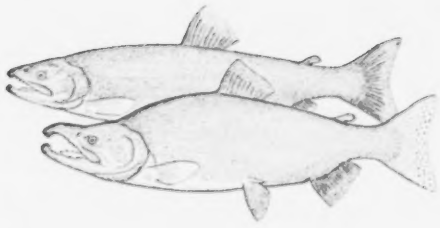
Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2012/033

ASSESSMENT OF AREA 23 SOCKEYE AND 2010 FORECAST (BARKLEY SOUND, ALBERNI INLET)



Sockeye Salmon (Oncorhyncus nerka)

Location of the three major Sockeye stocks contributing to the Area 23 terminal fishery, which occurs in Barkley Sound and Alberni Inlet off the west coast of Vancouver Island.

Context :

There are three major Sockeye Salmon stocks in Pacific Fisheries Management Area 23 (PFMA) (also referred to as Barkley Sound) on the west coast of Vancouver Island, of which Great Central and Sproat Lake stocks are the largest. The combined production from these two lakes averages about 655,000 fish and accounts for more than 90% of the total Sockeye run to the area based on 30 years of data. Henderson Lake supports a smaller but substantial Sockeye run averaging about 30,000 fish over the past 30 years. Fertilization continues for Great Central Lake alone. Supplementation and fertilization efforts for Henderson lake have been suspended.

PFMA 23 stocks are currently the only Sockeye populations on the west coast of Vancouver Island (WCVI) with sufficient production to support directed fisheries. The fishery targets Great Central Lake and Sproat Lake Stocks, with measures in place to avoid the smaller and less productive Henderson Lake stock. Fish are harvested by First Nation, recreational and commercial harvesters.

In support of annual fisheries planning, an annual pre-season forecast of the expected adult return is requested by Fisheries and Aquaculture Management (DFO). The pre-season forecast is revised during the fishing season, based on data gathered through a test fishery, catch monitoring, and escapement enumeration.

This Science Advisory Report is from the May 26 & 27, 2010 Cultus Lake Sockeye Stock Status, 2010 Barkley Sound Sockeye Forecast, 2010 West Coast Vancouver Island Chinook Abundance Forecast, and Fraser River Sockeye Spawning Initiative Meeting. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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Canada

SUMMARY

- There are three major Sockeye Salmon stocks in Pacific Fisheries Management Area 23 (PFMA) (also referred to as Barkley Sound) on the west coast of Vancouver Island, of which Great Central and Sproat Lake stocks are the largest with a combined production averaging 655,000 fish annually (1980-2009 average annual total return). Henderson Lake supports a smaller, but substantial, Sockeye run averaging 30,000 fish annually (1980-2009 average annual total return).
- For the three major stocks, enhancement tools have been used to increase production, or in the case of Henderson Lake, stabilize production.
- From 1997 to 2007, the harvest rate of Area 23 Sockeye fisheries was estimated at 29%, 33% and 13% for Great Central, Sproat and Henderson Lake Sockeye populations, respectively.
- The 2009 terminal return of Sockeye to the Somass River system was estimated to be 440,000 adults, approximately 26% greater than the management forecast of 350,000. Henderson Lake Sockeye abundance has been well below the long term average through the last decade.
- The 2010 pre-season forecast to the Somass system is 600,000 fish (90% probability range from 350,000 to 850,000 fish). The 2010 forecast is near the long term average annual total return and represents an increase of approximately 35%, over observed 2009 returns. Henderson Lake escapement in 2010 is expected to be below the target escapement of 50,000 fish.

BACKGROUND

Species Biology

Sockeye Salmon are typically anadromous and populations originating from Barkley Sound and the West Coast of Vancouver Island occupy the southern end of the species range in North America. Sockeye originating from these coastal systems, as opposed to interior of British Columbia, spawn in gravel in lake beaches and rivers from late August to December. Juvenile Sockeye rear from 1 to 3 years in fresh water, prior to smoltification and migration to ocean feeding areas. Less common sea-type Sockeye migrate to sea much sooner after emergence. Age at maturity is typically 4 to 5 years (range 3-6). Fecundity is correlated with size at return and varies considerably among populations from 2000 to 5000 eggs per female.

The period of highest mortality in the salmon life cycle is the early marine phase just after smolting. Early marine mortality rates of WCVI origin salmon are typically about 95%, although mortalities of greater than 99% have been observed periodically. Marine survival is associated with changes in ocean productivity, such as the availability of prey to juvenile salmon or density of predators.

Conservation Units for salmon are determined based on the genetic, morphological, behavioral and ecological similarity of populations. Four Conservation Units (CUs) of lake-type Sockeye salmon are designated for the Barkley Sound area; including Great Central, Sproat, Henderson and Maggie Lakes. River-type populations originating from Barkley Sound are part of the larger WCVI "river-type" Sockeye Conservation Unit, which is comprised of more than 60 separate populations. Five of these populations originate from Barkley Sound; including Carnation Creek, Effingham River, Nahmint River, Sarita River and Toquart River.

Enhancement

Great Central Lake was fertilized initially from 1970 to 1973 and then annually since 1977. Sproat Lake was fertilized for part of 1985 and the summer of 1986. Henderson Lake was fertilized from summer 1976 to 1998.

Interventions to stabilize Henderson Lake Sockeye have included hatchery supplementation and lake fertilization (suspended in 1998) and habitat restoration. Henderson Lake Hatchery operated by the Uchucklesaht First Nation released fed Sockeye fry annually from 1992 to 2007. Total hatchery production ranged from about 70,000 to 2,300,000 fry annually.

Fishery & Fishery Management

Mixed-stock, mixed-gear fisheries operating in Area 23 on the west coast of Vancouver Island are managed based on the abundance and return timing of three Barkley Sound Sockeye stocks (Great Central Lake, Sproat Lake and Henderson Lake).

The fishery supports First Nations food, social, and ceremonial needs, First Nations economic opportunities, sport fishing, and commercial fisheries. The average annual catch was approximately 335,000 Sockeye between 1980 through 2009.

Prior to 1995, the two Somass populations (Great Central and Sproat Lake) were managed for fixed escapement objectives (350,000 Great Central and 150,000 Sproat Lake spawners). Since 1995, Somass River Sockeye have been managed based on a variable harvest rate. The harvest rate increases with abundance from 10% at run sizes above 200,000 to a maximum of 67% at 1.8 million. Only fisheries to meet assessment requirements, are permitted at returns below 200,000 (Figure 1). Fishery restrictions are in place to reduce the impact of the fishery on the less productive Henderson Lake population through time-area restrictions that utilize the migration and timing differences between the Henderson population and the two target Somass stocks.

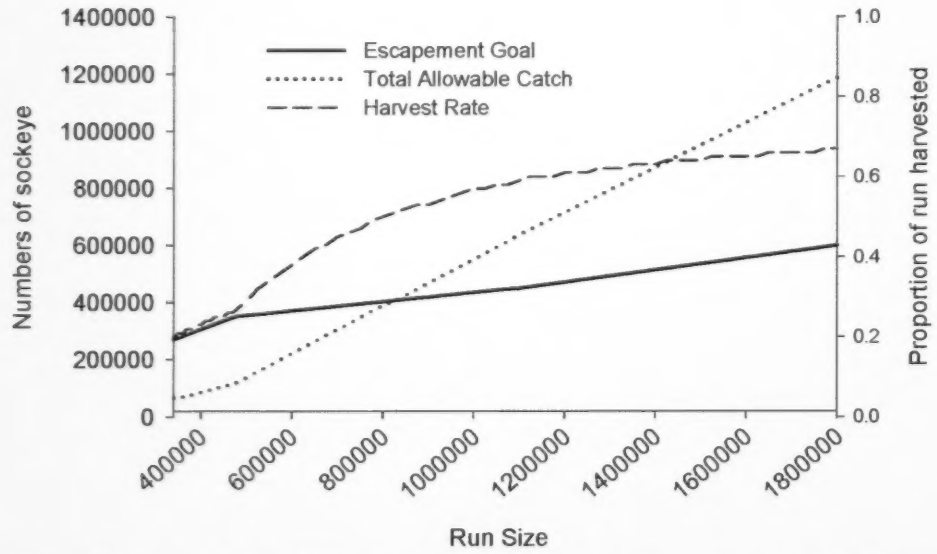

Figure 1. Somass Sockeye variable harvest rate strategy. The escapement goal and total allowable catch for run size on left y-axis. The allowable harvest rate for run size on the right y-axis.

Table 1. Average annual catch (fish) by harvest sector of Barkley Sockeye by decade, 1980 to 2009.

Decade	Sector				
	First Nation		Commercial	Recreational	Total
	Somas R.	Other Systems			
1980s	20,416	-	498,121	2,366	520,903
1990s	37,879	6,396	232,905	46,643	323,822
2000s	52,741	15,411	96,872	41,069	206,093

ASSESSMENT

Data & Methods

The information used in the stock assessment include data collected from the annual test fishery (1980 to 2009); the annual Sproat and Great Central Lake escapement monitoring programs (1979 to 2009); Henderson Lake escapement surveys (1977 to 2009); First Nation, commercial and recreational catch data (1979 to 2009); and annual acoustic trawl surveys of juvenile production in Sproat, Great Central and Henderson Lakes.

Stock Trends

Total Return

Annual returns for Area 23 Sockeye are cyclical (Figure 2). This cyclical pattern is largely explained by periodic variations in marine productivity, which correlates to larger-scale climatic variation in the Pacific Ocean (e.g. unfavorable El Nino events followed by favorable La Nina events). While, total returns for all three stocks have declined over the past 20 years, total returns of Somass Sockeye have declined less than those to Henderson Lake, which now makes up a lower proportion of Area 23 returns than in the historical period prior to 1970.

Sockeye returns to the Somass system were estimated at about 136,000 fish in 2007 and 135,000 fish in 2008, when totals were not only substantially below the 30-year average of 690,000 fish, but also below the provisional lower reference point of 200,000 fish required for fisheries.

Smolts originating from brood-year 2003 spawners exhibited a low smolt-to-adult survival. In addition, adult Sockeye returning to migrate through the Somass River during 2004 experienced super-optimal temperatures and associated migration delays of up to 9 weeks in duration.

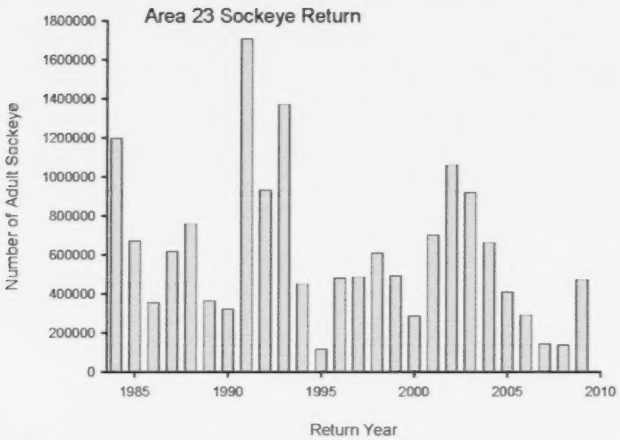

Figure 2. Combined return (escapement plus catch) of Area 23 Sockeye originating from Great Central, Sproat and Henderson lakes, 1984-2009.

Smolts originating from brood-year 2003 spawners exhibited a low smolt-to-adult survival. In addition, adult Sockeye returning to migrate through the Somass River during 2004 experienced super-optimal temperatures and associated migration delays of up to 9 weeks in duration.

Over the last 30 years, production of Area 23 Sockeye has declined (Table 2). While the high average returns in the 1980s were largely due to a few extremely high returns, the frequency of years with low returns has increased. There is also of evidence that the productivity of the Sproat Lake ecosystem has declined, as the average number of pre-smolts produced for each spawner has decreased over the last 10 years (Table 3).

Although lower than 20 to 30 years ago and still variable, Somass Sockeye production is relatively stable. In contrast, Henderson Lake Sockeye exhibited a pattern of decline starting about 1998, which may have recently reversed (Figure 3).

Table 2. Average adult return, catch and spawners (# of fish) of Area 23 Sockeye stocks, Great Central, Sproat and Henderson Lake Sockeye by decade (1980 to 2009).

Decade	Return	Catch	Spawners	Harvest Rate
1980s	857,900	478,600	379,300	0.48
1990s	696,900	318,600	378,300	0.35
2000s	508,000	212,900	295,100	0.33

Table 3. Average productivity statistics for Great Central (GCL) and Sproat Lake (SPL) Sockeye populations by decade (1980 to 2009).

Decade	Average Productivity		
	Returns per Spawner	Pre-smolts per Spawner	Returns per pre-smolt
1980s	GCL 2.0 SPL 2.4	GCL 45 SPL 68	GCL 5.0% SPL 5.0%
1990s	GCL 2.1 SPL 2.0	GCL 53 SPL 63	GCL 5.0% SPL 3.4%
2000s	GCL 1.7 SPL 1.4	GCL 40 SPL 47	GCL 3.5% SPL 2.7%

Escapement

Escapement trends for Great Central, Sproat Lake and Henderson Lake are summarized in Figure 3. No reliable time series are available for other Barkley Sockeye stocks (e.g. Maggie Lake or 'river-type' Sockeye). Escapement since 1995 has been above the lower fishing limit of 200,000; averaging about 173,000 and 133,000 spawners in Great Central and Sproat Lakes, respectively (1984 to 2009).

Escapement to the Henderson system has shown an improvement over the last few years, after several years of sustained decline. The estimate of escapement to the Henderson system in 2009 was approximately 30,000; approximately equal to the long-term average of 35,000. However, this return includes production from the Henderson Lake hatchery, which ceased operations after the 2007 brood year. Based on the recovery of marked juveniles in spring 2004 sampling, a maximum of 30% of smolts were of hatchery origin.

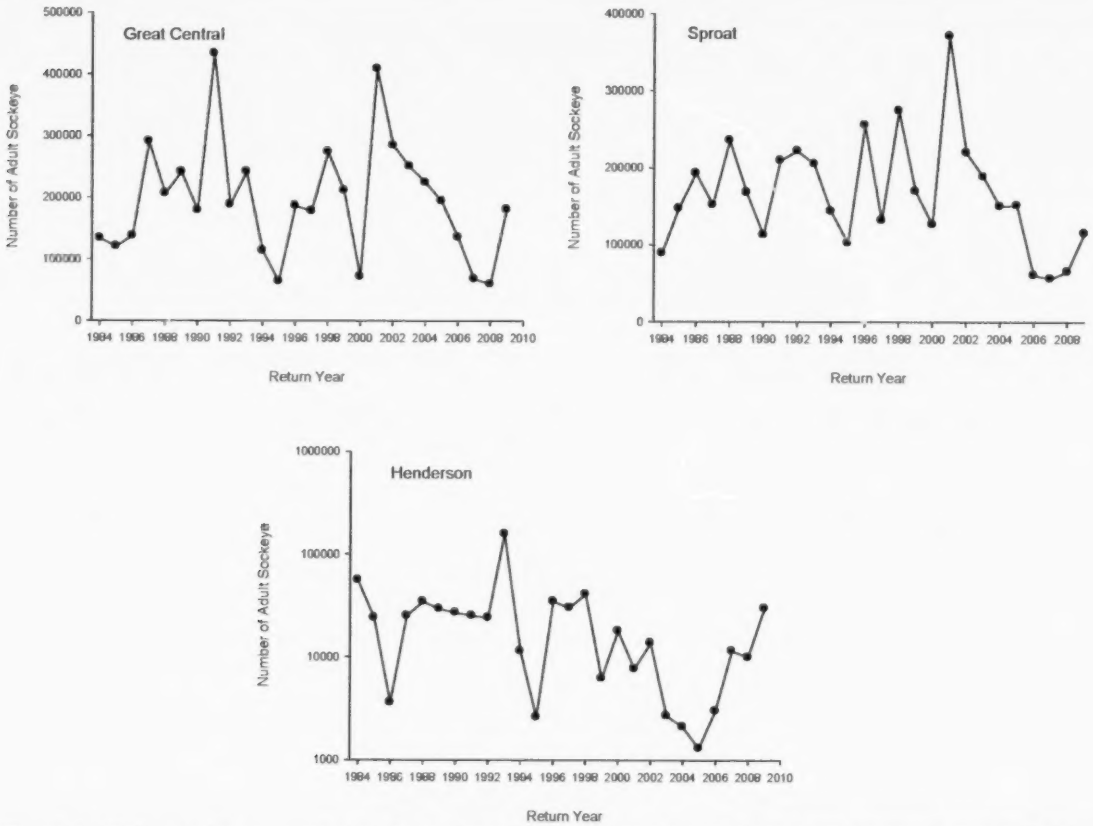

Figure 3. Estimated escapement of Great Central, Sproat and Henderson Lake Sockeye populations, 1984-2009. Note log scale on y-axis for the Henderson graph.

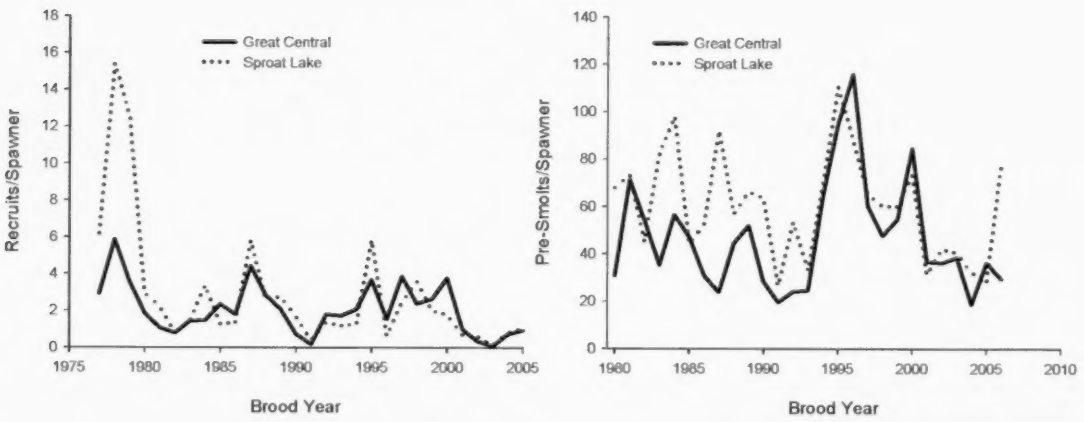

Figure 4. Productivity (recruits/spawner) trends for Somass Sockeye populations (Great Central and Sproat Lake). The left graph is adult recruits per spawner. The right graph is pre-smolts per spawners.

Juvenile Production

Estimates of juvenile production of sockeye from Great Central, Sproat and Henderson Lake sockeye are summarized in Figure 4. For all three populations smolt production is highly variable. Some indication of recent declines in production are apparent, although it is not yet clear this is a sustained trend.

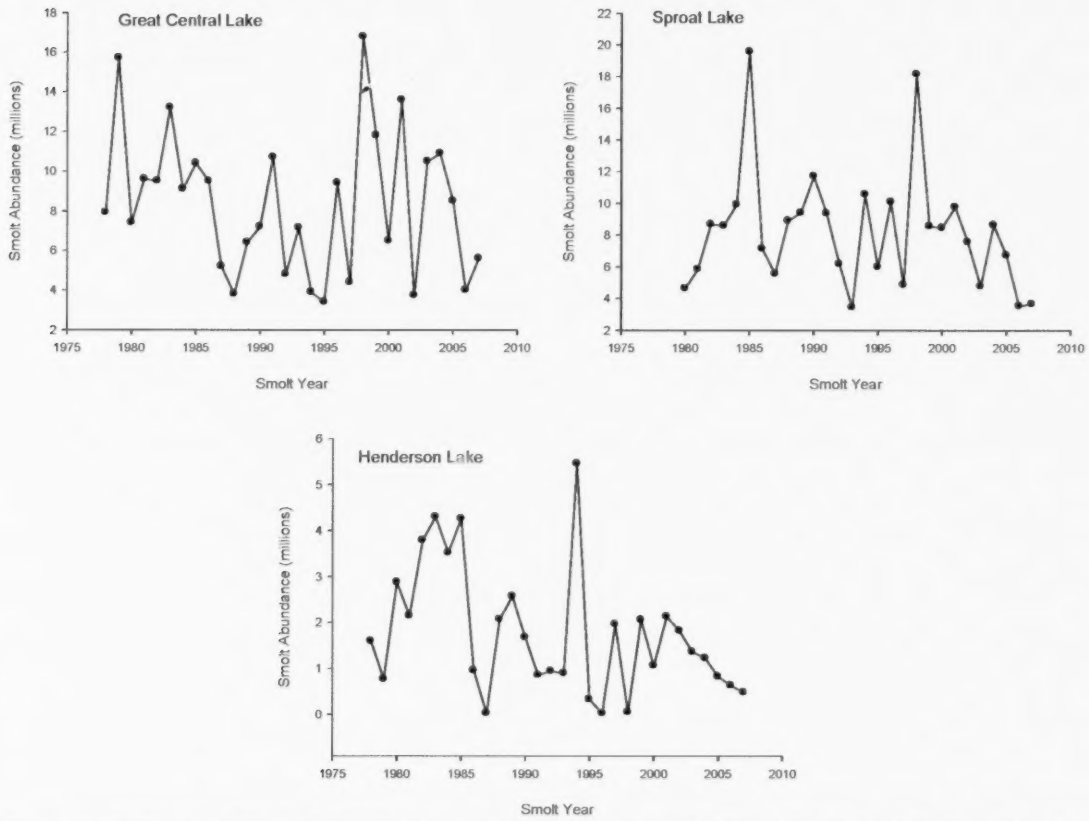

Figure 5. Estimates of juvenile Sockeye production (fall pre-smolts) from Great Central, Sproat and Henderson Lakes, 1977 to 2007.

Marine survival rate

Marine survival rate is not directly estimated for Barkley origin Sockeye stocks, as, these stocks are not marked. However, survival rate is estimated by computing the ratio of estimated smolt abundance (as determined by annual acoustic trawl surveys of Great Central and Sproat Lakes) to total return by stock (Figure 6). These data exhibit that cyclic aspect of marine survival rate. There is some indication of improvement over the last few sea entry years (i.e. starting in 2006), coincident with observations of cooler water off the WCVI. However, a new warming trend, that began in late 2009 and continued through sea-entry year 2010, may lead to reduced marine survival of Sockeye smolts in spring 2010 and the possibility of reduced adult returns in 2012.

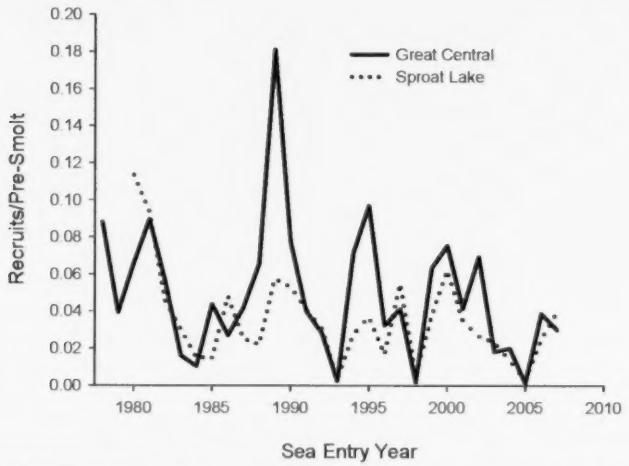

Figure 6. Estimate of adult recruits per pre-smolt; an index of marine survival rate of Somass Sockeye populations, 1977 to 2007 sea entry years.

Catch and exploitation rate

Catch and exploitation rate trends for Somass stocks are summarized in Figure 7. Over the last 30 years, the average catch in the Barkley Sockeye fishery is about 336,000 corresponding to an average harvest rate of about 38% (Figure 7). An exploitation rate model using the results of the catch composition studies suggests that between 1997 to 2007, the average exploitation rate of the Area 23 Sockeye fisheries was 29%, 33% and 13% for Great Central, Sproat and Henderson Lake Sockeye populations, respectively (Figure 8 and Labelle 2009).

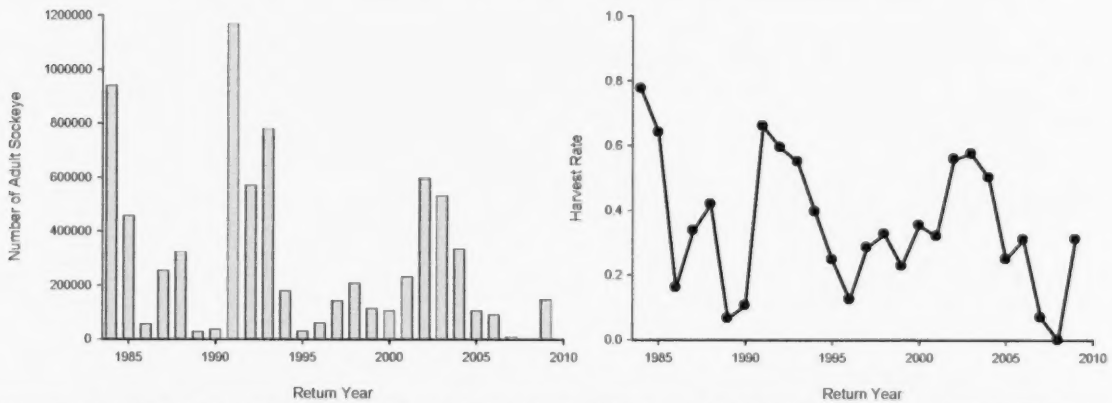

Figure 7. Estimated catch (left graph) and harvest rate (right graph) of Area 23 Sockeye, 1984-2009, including Great Central, Sproat and Henderson populations.

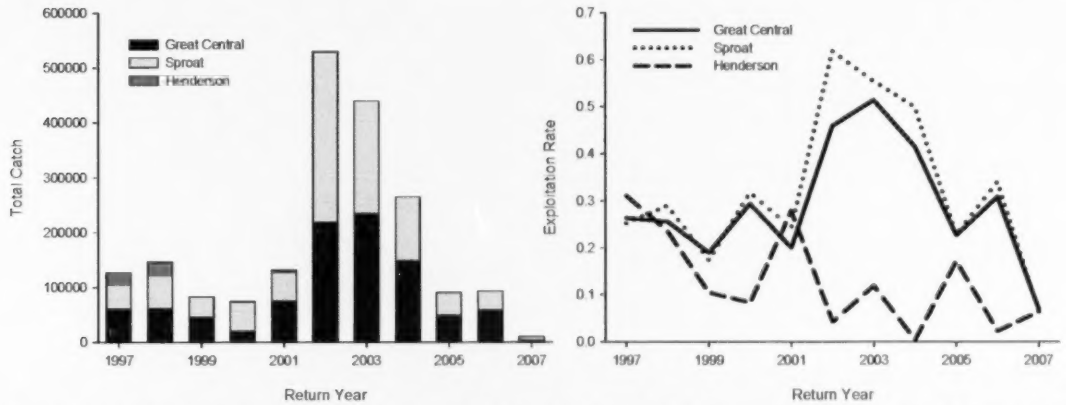

Figure 8. Estimated stock contribution to the Area 23 fishery (left graph) and stock-specific exploitation rates (right graph).

2010 Forecast

For management purposes, a single aggregate forecast of adult returns to the two Somass River populations (Great Central and Sproat Lake) is used to set pre-season expectations and to guide early-season management.

The forecasting process involves four scientifically reviewed methods: the Survival Stanza Method (SStM), Surface Salinity Method (SSM), Salmonid Enhancement Program Biostandard Method (SEPB), and Coho Leading Indicator Method (CLI). Three of the four (SStM, SSM, SEPB) use annual estimates of the numbers of smolts from Great Central and Sproat Lakes and correlates of early marine survival to predict returns, and the fourth uses marine survival estimates for coho salmon from the same smolt years to predict return from average smolts per adult Sockeye spawner.

Recently, two additional methods have augmented forecasts for Barkley Sockeye. The Euphausiid Forecast predicts returns based on relationships between spring biomass of specified size range of these invertebrates that some information suggests juvenile Sockeye feed on and estimates of subsequent Sockeye marine survival. A sibling-based forecast is also generated, using relationships between the returns of Sockeye at earlier ages to predict future returns of their older siblings (i.e. predicts age-4 and age-5 returns based on the abundance of age-3 and age-4 returns respectively). The forecasts generated from all six methods are compared and based on their correspondence and relative accuracy at predicting past returns a single management forecast is produced in March each year.

Forecasts for the 2010 Barkley Sockeye return range from a low of 145,000 (SSM forecast) to a high of 657,000 (Euphasiid forecast) for the two Somass River populations. The forecasts that have performed best in past years suggest adult returns of about 425,000, 645,000, 657,000, and 570,000 for the SStM, CLI, Euphaussid, Sibling models, respectively (Table 4).

Based on integration of information from all forecasts, and evaluation of past performance, the pre-season forecast of adult Sockeye returning to Barkley Sound in 2010 is 600,000 (90% probability range from 350,000 to 850,000 fish).

The return of Henderson Lake Sockeye is not forecast through analytical models, rather brood year spawning abundance is used to provide a qualified assessment. As there were low

numbers of spawners in both of the brood years (2005, 2006) that will contribute to the 2010 return, the outlook is for low abundance.

Table 4. Forecast results for 2010 from alternative Barkley Sockeye models. Mean Absolute Percentage Error (MAPE) is the average percent difference between observed and forecast return over years the model has been used.

Probability of a lower return	Forecast Method					
	SStM	SSM	SEPB	CLI	Euphausiid	Sibling
0.75	606,706	654,678	662,527	856,306	1,187,169	932,116
0.5	**423,275**	**114,469**	**380,947**	**645,481**	**656,522**	**571,671**
0.25	238,976	-	98,041	433,661	373,189	209,522
MAPE	35%	123%	85%	61%	-	54%

Sources of Uncertainty

The performance of pre-season forecasts is evaluated according to the deviation of observed return from forecast return. Expressed as a mean absolute percentage error (MAPE), on average the Somass Sockeye forecasts perform with a MAPE of 36 to 40%. That is, the actual return is typically 36 to 40% higher or lower than the pre-season forecast. In each of the past three years, the best performing model has over estimated the return.

CONCLUSIONS AND ADVICE

There are three major Sockeye salmon stocks in Area 23. The two stocks that return to the Somass River (Great Central and Sproat Lakes) are the largest, with a combined production averaging 655,000 fish annually (1980-2009 average annual total return). Henderson Lake supports a smaller, but substantial, Sockeye run averaging 30,000 fish annually (1980-2009 average annual total return. From 1997 to 2007, the harvest rate of Area 23 Sockeye fisheries was estimated at 29%, 33% and 13% for Great Central, Sproat and Henderson Lake Sockeye populations, respectively.

The 2009 terminal return of adult Sockeye to the Somass River system was estimated at about 440,000 adults, approximately 26% greater than the management forecast of 350,000. Henderson Lake Sockeye abundance has been below the long term average through the last decade. Interventions including hatchery supplementation (suspended in 2007), lake fertilization (suspended in 1998), habitat restoration and lower harvest rates have been undertaken in an effort to stabilize this stock.

The pre-season forecast to the Somass system for 2010 is 600,000 fish (90% probability range from 350,000 to 850,000 fish). Interim reference points for this system, established in 1994, are 200,000 fish (no fishing below) and 350,000 (estimate of spawner abundance at Maximum Sustainable Yield ($S_{msy,}$)). The 2010 forecast is near the long term average annual total return. Escapement expected to Henderson Lake in 2010 is expected to be below the target escapement of 50,000.

SOURCES OF INFORMATION

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